Autonomous Phase-Space Mapping and Navigation for Spacecraft Operations in Extreme Orbital Environments

Completed Technology Project (2012 - 2016)

Project Introduction

The objective of the proposed research is to generate a suite of algorithms for the autonomous navigation of highly nonlinear orbital regimes. These algorithms must fulfill several tasks, beginning with the computationally efficient generation of a map between the spacecrafts available maneuvering options and their corresponding trajectories. This map must then be automatically classified and organized based upon the outcome of each trajectory, such as escape, collision, or safe residence within the system. Subsequently, a planning algorithm must utilize this information to select a maneuver that optimally satisfies the safety requirements and science goals of the mission. Extensive consideration will be given to a variety of numerical integrators, ranging from traditional integrators such as the Bulirsch-Stoer method to energy-conserving symplectic integrators, for the most efficient propagation of individual trajectories. Computational expenses will be further managed by actively rediscretizing the total map of the system as particular regions are discovered to be nearly uniform or finely detailed. To aid in classification, the system map will be described within six-dimensional phase space, where each dimension represents one state variable of the spacecraft. Due to the property of uniqueness, sets of points may be conceptualized as enclosing volumes, which propagate through time as non-intersecting tubes within the phase-space. Once all mapped phase tubes have been classified, nonviable maneuvers will be discarded. Finally, a planning algorithm will select a maneuver to optimally satisfy an objective function derived from science goals, fuel policies, and other mission requirements. The proposed autonomous navigation algorithm would enable breakthrough abilities for science and exploration missions. Long-term orbits could be achieved about planetary satellites such as Europa and Enceladus, which are prime destinations of interest for astrobiological research due to the potential existence of tidally heated subsurface oceans of liquid water. Additionally, close proximity operations, landing, and sampling could be conducted at comets and asteroids. These bodies are desirable targets for the study of the early chemistry of the solar system, likely containing clues about planet formation and the origin of life-enabling organic compounds. Heightened autonomous navigation abilities would even prove useful for various methods of asteroid deflection, such as the dispersion of albedo-altering particles to cause a change in solar radiation pressure. The numerous technological benefits of the proposed research directly support the interests of NASA and the NSTRF program.

Anticipated Benefits

The proposed autonomous navigation algorithm would enable breakthrough abilities for science and exploration missions. Long-term orbits could be achieved about planetary satellites such as Europa and Enceladus, which are prime destinations of interest for astrobiological research due to the potential existence of tidally heated subsurface oceans of liquid water. Additionally,

Project Image Autonomous Phase-Space Mapping and Navigation for Spacecraft Operations in Extreme Orbital Environments

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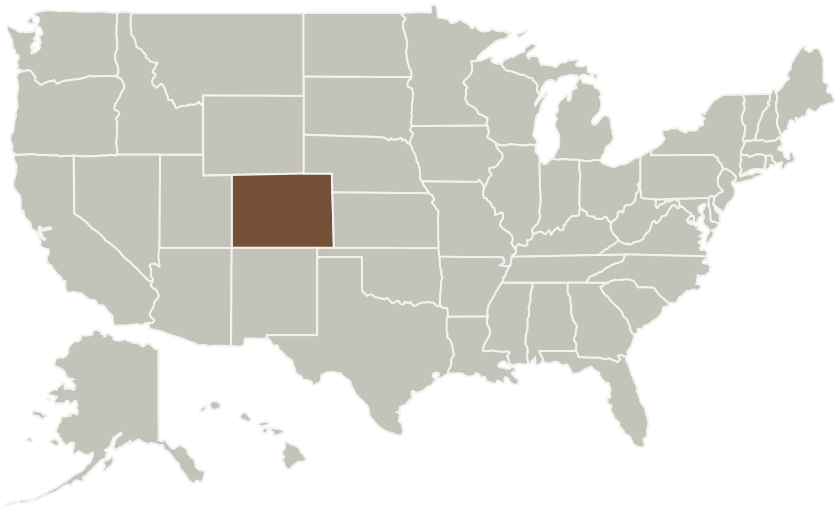
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Colorado Boulder	Supporting Organization	Academia	Boulder, Colorado

Primary U.S. Work Locations
Colorado

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

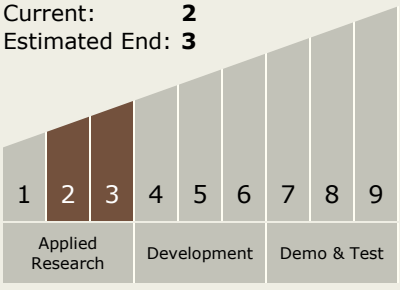
Daniel Scheeres

Co-Investigator:

David A Surovik

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



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Images

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Project Image Autonomous Phase-Space Mapping and Navigation for Spacecraft Operations in Extreme Orbital Environments
(https://techport.nasa.gov/image/1721)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Areas

Primary:

- TX17 Guidance, Navigation, and Control (GN&C)
  - TX17.2 Navigation Technologies
    - TX17.2.1 Onboard Navigation Algorithms